

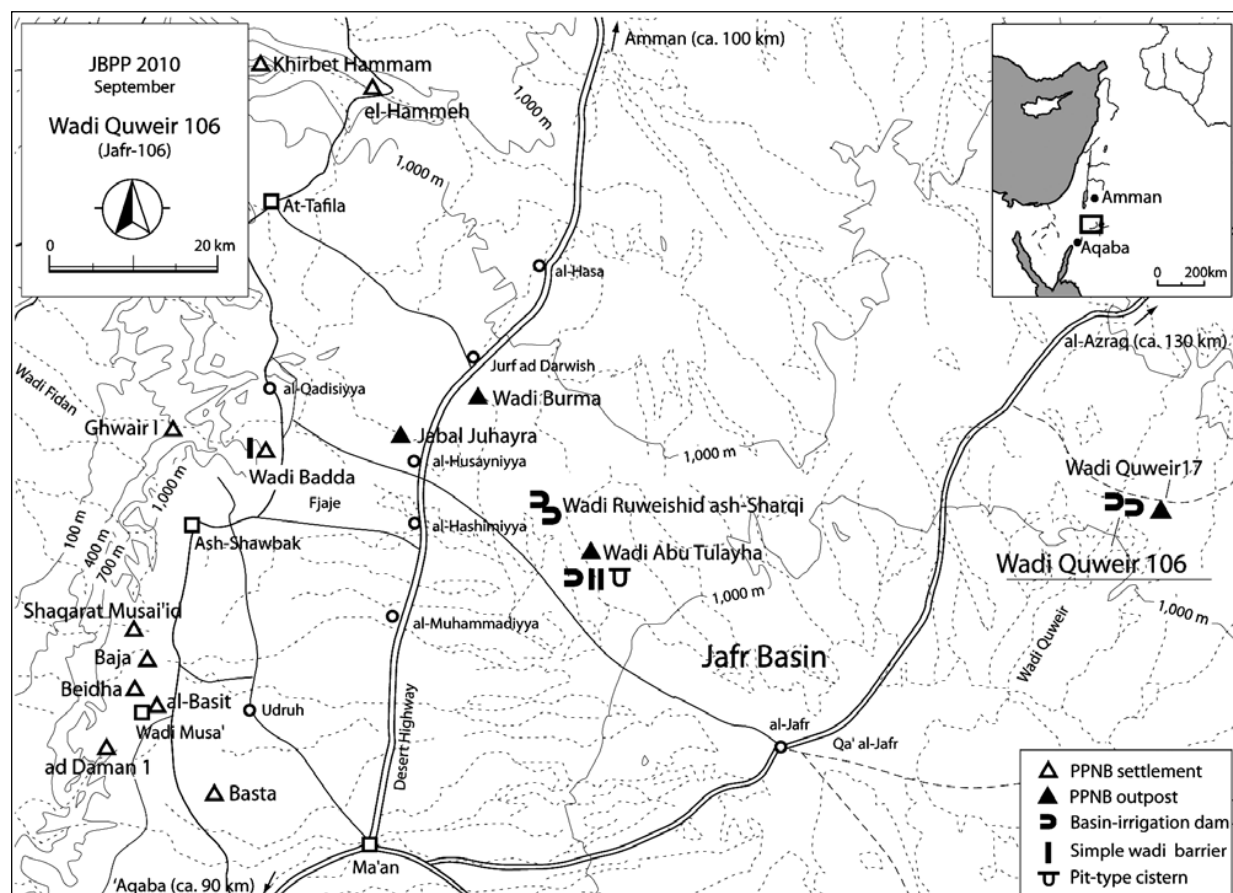
WĀDĪ GHUWAYR 106: A NEOLITHIC BARRAGE SYSTEM IN THE NORTH-EASTERN AL-JAFR BASIN

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Introduction

The 2010 summer field season of the Jafr Basin Prehistoric Project (JBPP) continued to address the correlation between pastoral nomadization and the Neolithic barrage system, a top priority issue for Phase 3 of the project (Fig. 1). The first two weeks were devoted to a rescue excavation at Wādī Ghuwayr 17, which proved to be a PPNB agro-pastoral outpost similar to

Wādī Abū Tulayḥa (Wilke and Quintero 1998; Fujii *et al.* this volume). Work then focused on the nearby barrage site of Wādī Ghuwayr 106 and explored its possible association with the PPNB outpost. Limited excavation of the barrage system corroborated our belief that pastoral transhumance during the Jafr PPNB was facilitated by water-catchment systems. The following is a brief summary of the investigation re-



1. Wādī Ghuwayr 106 and Neolithic water catchment facilities in the Jafr basin.

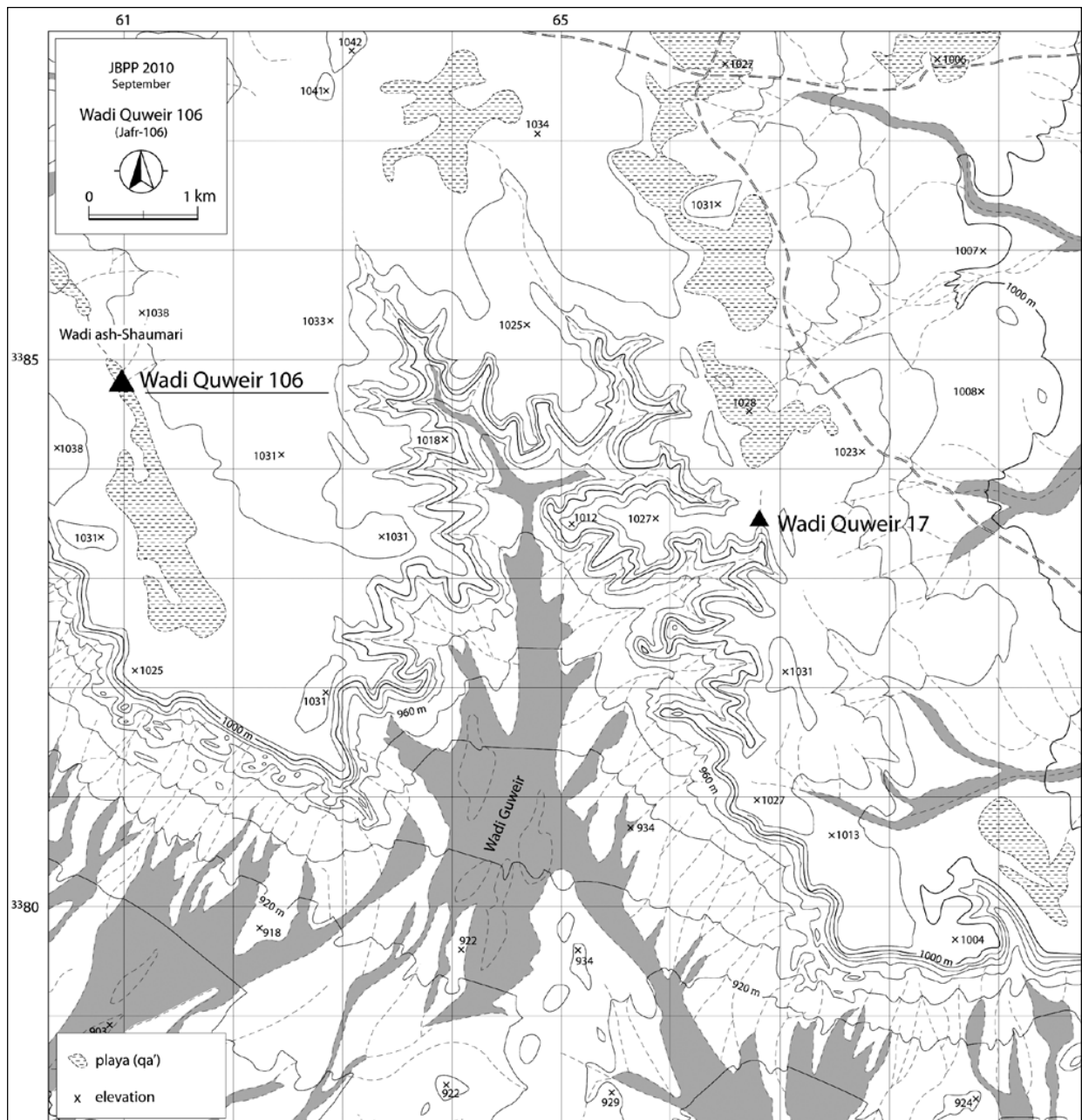
sults from this unique site.

The Site and its Setting

The site was discovered by two of us (LAQ and PJW) in 1999 during reconnaissance survey of the north-eastern Jafr Basin, which commenced in 1997. The site was officially registered as Jafr-106 and interpreted as a water-catchment site of mixed affiliation based on the presence of Thamudic and Islamic inscriptions on structural stones and a mixed lithic assem-

blage. For the subsequent rescue excavation, Jafr-106 was re-designated Wādī Ghuwayr 106.

The site of Wādī Ghuwayr 106 is located on upland terrain *ca.* 6km west-north-west of Wādī Ghuwayr 17 (Fig. 2). In terms of hydrology, the site is located at the head of Wādī ash-Shawmarī, the adjacent major drainage system in the northern part of the Jafr Basin. Thus the site name of Wādī Ghuwayr 106 is not strictly appropriate, but we use it for descriptive purposes to indicate one of a number of archaeological sites around



2. Research area and location of Wādī Ghuwayr 106.



3. Wādī Ghuwayr 106: distant view of the site (looking north-west).

the head of Wādī Ghuwayr. The site is a simple, open-air site that consists only of two elongated freestanding stone-built walls. It is isolated in the middle of a flint pavement desert (Ar. *al-Hamād*) and appears not to have been associated with a settlement in terms of its operation (Fig. 3). The two wall alignments occupy flat terrain on the northern half of an elongated playa (Ar. *Qā'*) (Fig. 4). This playa, *ca.* 550m long and up to *ca.* 100m wide, is the lower component of a semi-open playa system that forms the upper reaches of one of the headwater forks of Wādī ash-Shawmarī. The two walls are located at the lowest part of the semi-open playa system, a key to understanding the location and function of the PPNB barrage system.

The Investigation

Investigation began with the setting up of two arbitrary leveling points (elevation *ca.* 1,020m) near the two wall alignments. Since the mapping area was both extensive and monotonous in topography, we abandoned production of a contour map and instead plotted the outline of the relevant natural features and measured relative elevations of the major axis and several perpendicular axes of the playa (Fig. 4). We then returned to the two stone walls and surveyed *in situ* wall materials at intervals of *ca.* 5-8m. The general plans of the two walls were produced by plotting out these marked points.

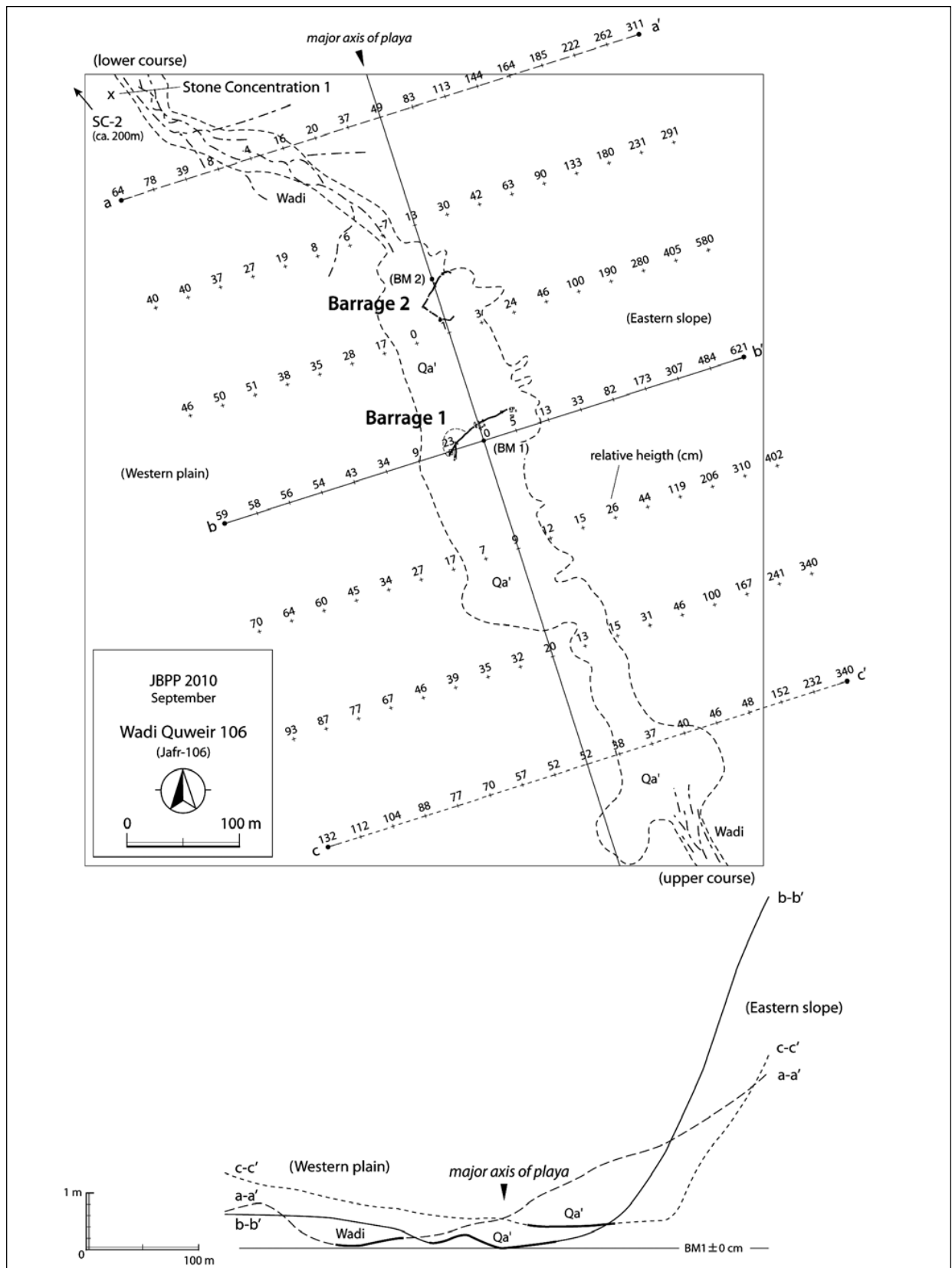
Since their role as water catchment facilities was obvious, we designated the two fea-

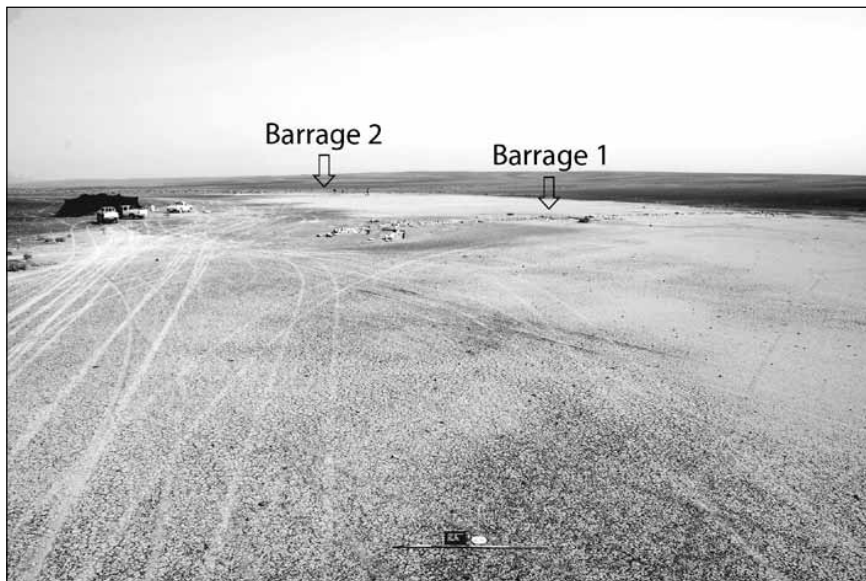
tures Barrage 1 and Barrage 2, in descending order of elevation from south to north (Figs. 5 and 6). Barrage 1 was intensively examined by means of six small trenches. The exposed wall segments had a total length of *ca.* 18m, or approximately one-fifth of the total length of the barrage wall. Barrage 2, on the other hand, was quickly sounded by two small trenches. The two central trenches (i.e. Area 3 of Barrage 1 and Area 1 of Barrage 2) were set up along the major axis of the playa, but the other excavation areas were arranged along a magnetic north - south line. Excavated deposits were not sieved owing to the extreme scarcity of small finds, but a total of 20 liters of basal soil deposits were collected for flotation to retrieve any preserved organic remains. At time of writing this analysis has yet to be completed.

Unlike Wādī Ghuwayr 17, the site stratigraphy of Wādī Ghuwayr 106 was very simple and, apart from the retaining bank described below, every excavation area contained fluvial silty deposits only. Layer 1 or the surface layer was *ca.* 10-15cm thick and consisted of light buff, compact, silty sand deposits. Layer 2 was at least *ca.* 20cm thick, containing light brown, highly consolidated, silty sand deposits. The two barrages were constructed on the upper surface of Layer 2.

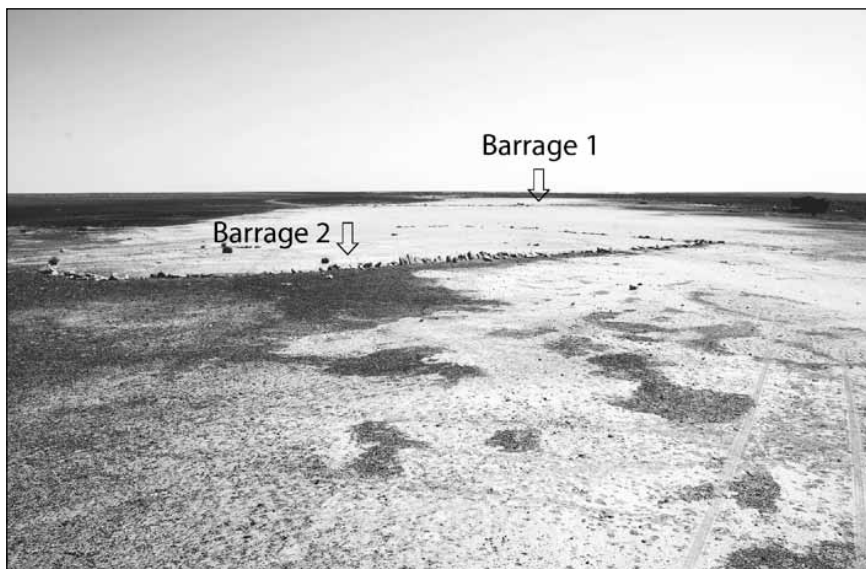
Excavation of Barrage 1

Barrage 1 is located at a point *ca.* 400m downstream of the inlet to the elongated playa, or *ca.* 150m upstream of its outlet; in other words,





5. Wādī Ghuwayr 106: general view of the barrage system (looking north).

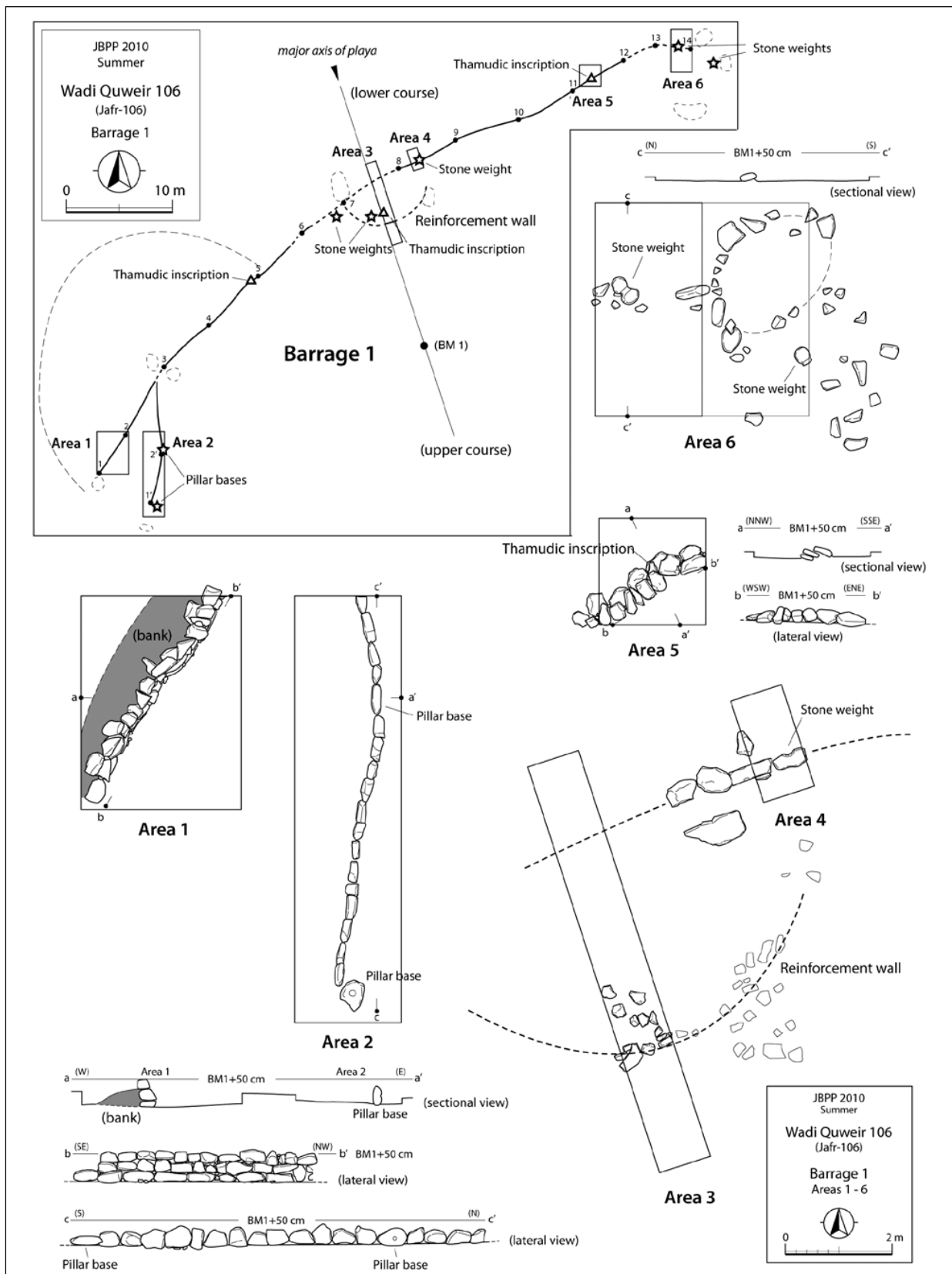


6. Wādī Ghuwayr 106: general view of the barrage system (looking south).

roughly in the middle of its northern half. It was constructed across the playa, being oriented to the south-south-east (**Fig. 4**). The barrage wall has a total length of *ca.* 72m and is preserved to a height of up to *ca.* 0.4-0.5m above the modern ground surface, being slightly incurved toward the upstream direction (**Figs. 7, 8 and 9**). As fallen stones around the wall are scarce, it is conceivable that there is little difference between its preserved and original heights. In fact, the preserved wall height is roughly equivalent to the elevation of the uppermost part of the playa and as such would have been able to submerge an area of *ca.* 2-3ha. This estimated flooding area of 2-3ha is similar to that of Barrage 1 at Wādī

Abū Ṭalayḥa (Fujii 2007b), suggesting that this may have been a standard characteristic of such constructions in the Jafr PPNB.

The barrage wall was constructed of a single row and up to three to four courses of undressed or part-dressed limestone cobbles and boulders *ca.* 30-80cm long. Dry stone walling appears to have been the norm; no clear evidence for clay mortar was found with the sole exception of the retaining bank in Area 1. Construction material probably originated from the wadi bed *ca.* 200-300m downstream, where similar stones are exposed by erosion. Overall, the wall alignment was simple in structure; additional features were limited to a semi-circular reinforcement wall



7. Barrage 1: plans and sections / elevations.



8. Barrage 1: general view (looking north-east).



9. Barrage 1: general view (looking south-west).

in the centre and an extra wall segment at the south-west end.

Area 1

Area 1 was established to examine the structure of a well-preserved wall segment at the south-west end of the barrage. The excavation revealed a masonry wall *ca.* 4.5m long and up to *ca.* 0.5m in preserved height, which was constructed of a single row and three courses of undressed or part-dressed limestone cobbles (Figs. 7 and 10). The masonry was of high quality and every course was laid horizontally, using small pieces of flint and limestone rubble as adjusters.

The foundation course utilised a stretcher bond, but the upper courses were eclectic in nature, being laid in both stretcher and header

bond. This construction technique is reminiscent of Barrage 1 at Wādī Abū Ṭulayḥa (Fujii 2007b: Fig. 8, 2007c: Fig. 6). No clear evidence for clay mortar was confirmed, but a clay bank was found to the rear of the wall segment (Fig. 11). This retaining bank, *ca.* 0.3m high and *ca.* 1m wide, was probably added for both waterproofing and structural reinforcement of the barrage wall.

Area 2

The excavation at Area 2 explored the nature of a short wall segment attached to the south-west end of the barrage. This additional wall was *ca.* 7m long and up to *ca.* 0.3m in preserved height, being built of a single row of upright limestone slabs (Figs. 7, 10 and 11). Neither foundations



10. Barrage 1: Area 1 (above) and Area 2 (below) (looking north-west).



11. Barrage 1: Area 1 (below) and Area 2 (above) (looking south-east); white arrow shows bank to rear.

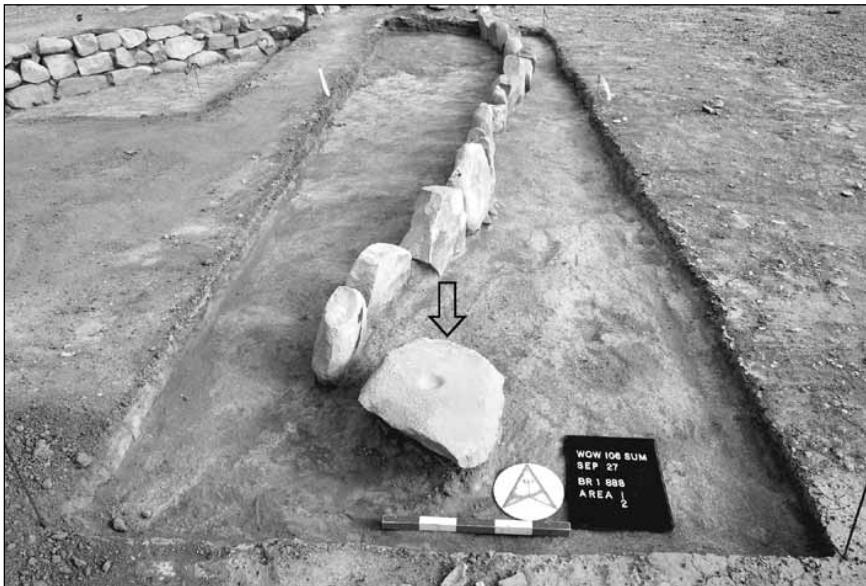
nor supporting elements to the rear were confirmed. It appears that the wall was added to reduce the strong sideways water pressure against the barrage wall. It is probably for this reason that it was much simpler in structure than the main wall. Interestingly, no similar device was confirmed at the opposite, north-eastern edge of the barrage. This is probably because this part is (and presumably was) *ca.* 20cm higher than the south-western part and therefore had less water pressure to contend with. It is an ironical outcome that although the south-west end of the barrage wall was well-preserved owing to the protection afforded by the additional wall, the

north-eastern edge was washed out as a result of its absence.

The wall segment included two socketed limestone pillar bases (see below): one as a fallen stone at its southern end (**Figs. 12 and 33: 1**) and the other as an *in situ* item incorporated into its northern part (**Figs. 13 and 33: 2**). As discussed below, these diagnostic finds provide a key to exploring the date of the barrage.

Areas 3 and 4

These two excavation areas were opened to examine the central part of the barrage. Though heavily damaged by seasonal floods, the excava-



12. Barrage 1: pillar base found at the southern edge of Area 2 (looking north).



13. Barrage 1: pillar base incorporated into the barrage wall of Area 2 (looking south-west).



14. Barrage 1: Area 3 (center) and Area 4 (right) (looking north).

tion revealed traces of a semi-circular, protruding reinforcement wall, as well as the aligned foundation stones of the barrage wall (Figs. 14 and 15). The existence of the reinforcement wall at the crucial central part of the barrage, where it would have been subjected to the greatest water pressure, is a feature of all the PPNB barrages discovered to date in the Jafr Basin, suggesting that it may have been a standard element in their construction (Fujii n.d.a). It is probable that, as in the case of Barrage 1 at Wādī Abū Ṭulayḥa (Fujii 2007b: Fig. 9, 2007c: Fig. 5), the inner part of the reinforcement wall was originally packed with clay and rubble.

These two excavation areas yielded three large, bilaterally notched and / or bifacially grooved stone weights: two as stray finds around Area 3 (Figs. 16, 17 and 32: 1-2) and



15. Barrage 1: Area 3 (center) and Area 4 (left) (looking south-west).



16. Barrage 1: stone weight found beside Area 3 (looking north-east).



17. Barrage 1: stone weight found beside Area 3 (looking north).

the other as a foundation stone in the wall segment of Area 4 (Figs. 18 and 32: 3). The occurrence of diagnostic stone weights – especially in the seemingly ubiquitous reinforcement wall

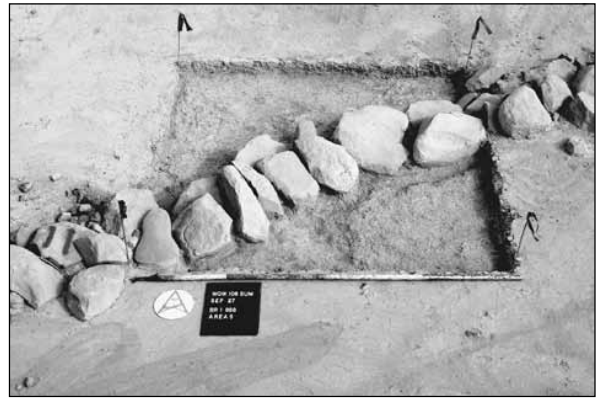


18. Barrage 1: stone weight incorporated into the barrage wall of Area 4 (looking south-east).

– is typical of dated PPNB barrages in the western Jafr Basin (Fujii 2010a, n.d.a), suggesting chronological synchronicity with them. In addition, a Thamudic or Hismaic IV inscription was recovered as a stray find in the southern part of Area 3, between the barrage and reinforcement walls (Fig. 19).

Area 5

This small excavation area explored the chronological correlation between the barrage wall and a Thamudic inscription incorporated into it (Fig. 20). The inscribed slab was partly covered by other construction material and therefore appeared to be an original component of the barrage wall (Fig. 21). If this had been the case, the barrage would necessarily have post-dated the Thamudic inscription. However,

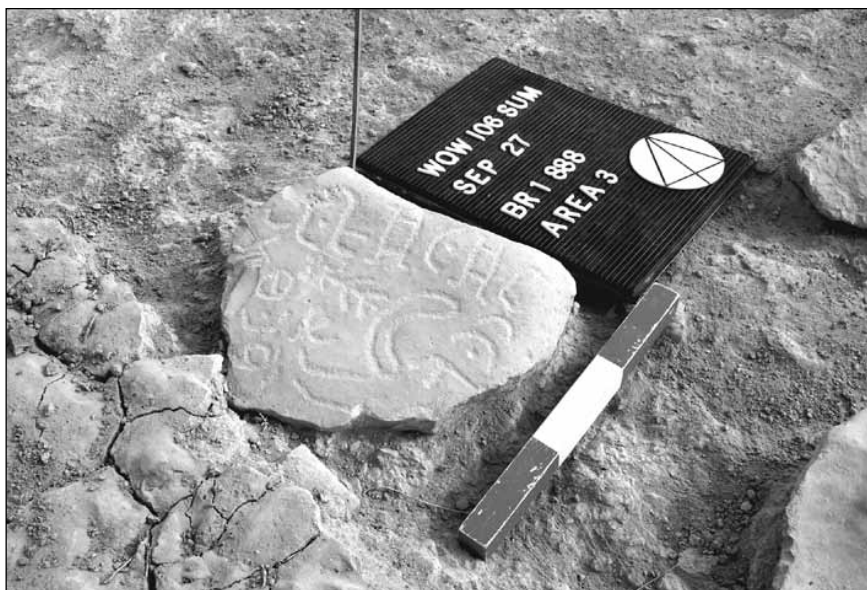


20. Barrage 1: Area 5 (looking north).



21. Barrage 1: Thamudic inscription incorporated into the barrage wall of Area 5 (looking west).

closer scrutiny revealed that – as was the case with similar stones nearby – the inscribed slab was leant up against foundation stones, with a minor stratigraphic gap between them. Thus, the uppermost stones, including the inscribed slab,



19. Barrage 1: Thamudic inscription found at the edge of Area 3 (looking north-east).

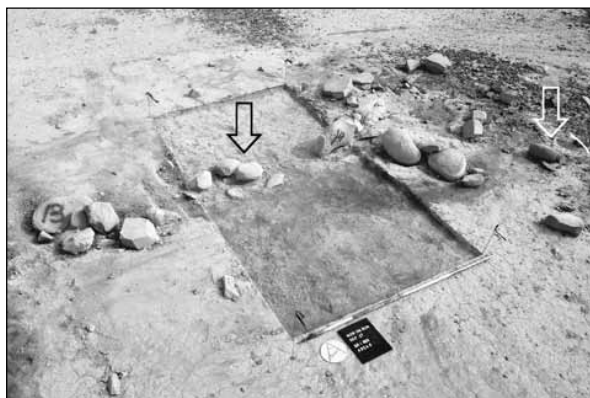
can be regarded as later additions or modifications. Supporting this interpretation is the structure of wall segment 4 / 5 where another *in situ* Thamudic inscription occurred. Here again, a two-phase structure similar to Area 5 was confirmed (**Fig. 22**). These observations suggest that the two inscribed slabs were incorporated into the wall during the course of *ad hoc* maintenance work during the first millennium AD, or later, indicating re-use of a much older water catchment system.

Area 6

The excavation in Area 6 examined the archaeological context of a notched and grooved stone weight that was exposed near the north-east end of the barrage. The excavation confirmed that it was among the remnants of the washed-out barrage wall (**Figs. 23 and 32: 4**). In addition, a halved stone weight was found outside the excavation area, at the very end of the barrage wall (**Figs. 24 and 33: 1**). There is little doubt that this artifact also derived from



22. Barrage 1: Thamudic inscription incorporated into wall segment 4 / 5 (looking north-east).



23. Barrage 1: Area 6 (looking north-east).



24. Barrage 1: halved stone weight found beside Area 6 (looking south-east).

the washed-out wall.

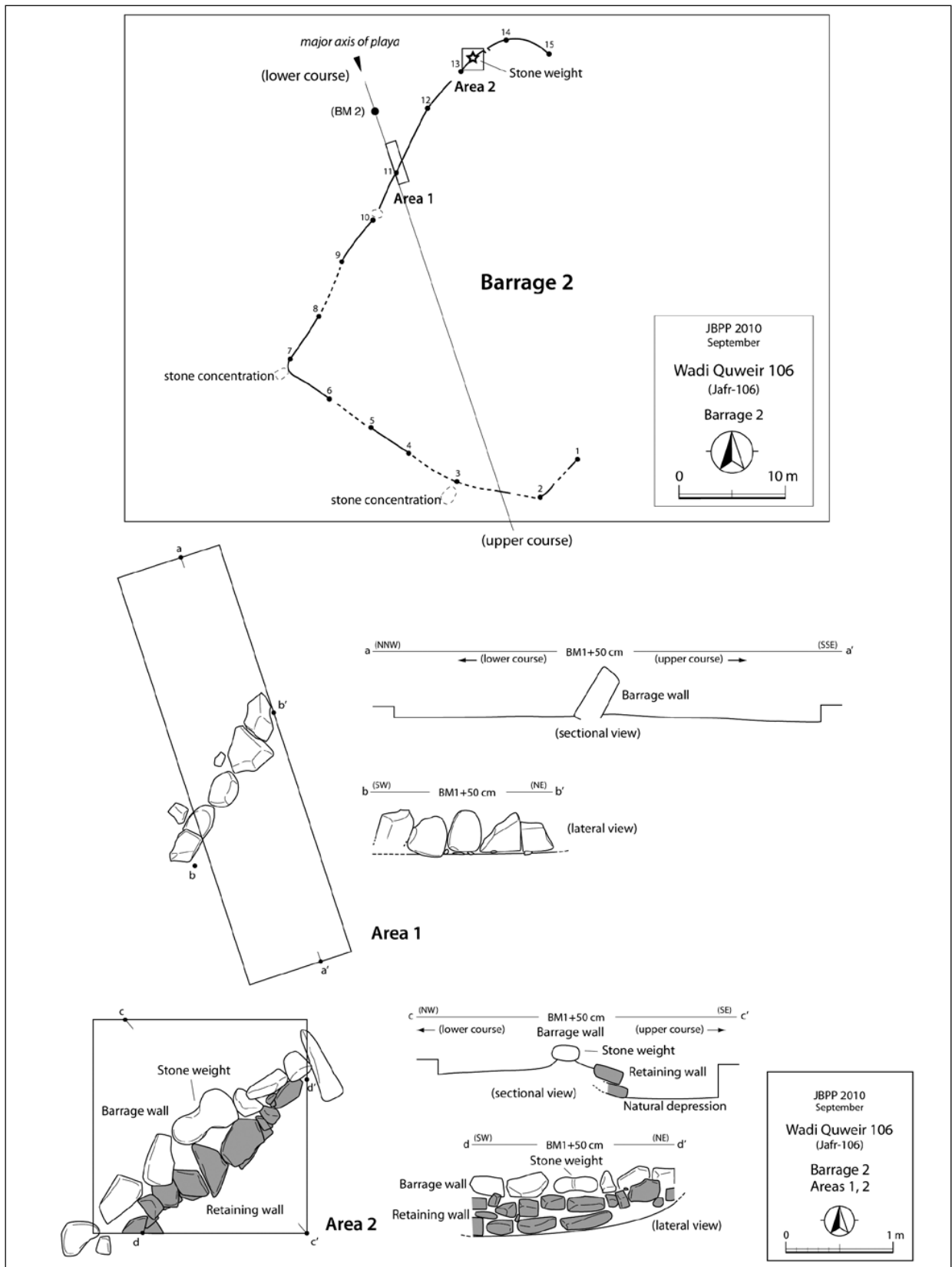
In contrast to the south-west end, the north-east end of the barrage was not equipped with a reinforcement wall to protect against the strong water pressure. As noted above, this is probably because it was higher in relative elevation and therefore subject to less pressure. Presumably, it is for the same reason that this part of the barrage wall was less substantially constructed. We can argue that such structural deficiencies were exposed by a wash-out.

Excavation of Barrage 2

Barrage 2 is situated *ca.* 130m north of Barrage 1, near the present outlet of the playa (**Fig. 4**). It deviates slightly from the shorter axis of the playa, being oriented to the south-east. The barrage wall was L-shaped in general plan, measuring *ca.* 74m in total length and *ca.* 0.4-0.5m in preserved height (**Figs. 25, 26 and 27**). Unlike Barrage 1, this barrage had neither a protruding reinforcement wall nor any other additional wall.

Area 1

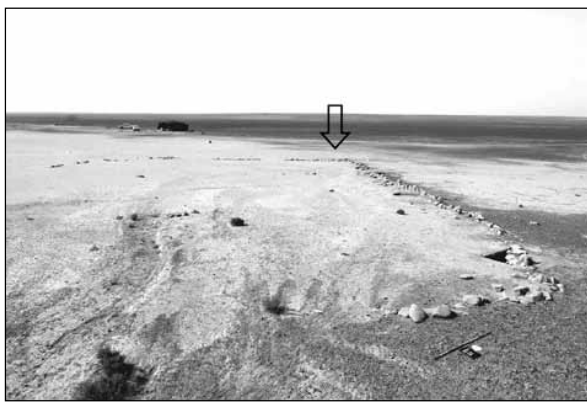
The excavation at Area 1 was intended to clarify the structure of an upright slab wall that characterizes the central part of the barrage. The excavation showed that all construction material was placed directly on the playa surface without any foundations or support to the rear (**Figs. 25, 26, 27 and 28**). The wall itself was carefully constructed so as not to leave a significant gap between any two adjacent stones, but no clear evidence for clay mortar was found. This was also the case with Barrage 1 and the other parts



25. Barrage 2: plan and sections / elevations.



26. Barrage 2: general view (looking west).



27. Barrage 2: general view (looking south-west).



28. Barrage 2: Area 1 (looking north).

of Barrage 2, suggesting that it was not always essential for these barrages to be perfectly waterproof. However, most of the construction materials were placed at a slight angle, suggesting that the wall was constructed to withstand a degree of water pressure against it.

Area 2

This excavation area examined the archaeological context of a bilaterally notched stone

weight that was partly exposed near the north-eastern end of the barrage (Figs. 25 and 29). Excavation confirmed that this diagnostic artifact was incorporated into the wall segment 13 / 14 at the time of its initial construction and can therefore be regarded as a chronological indicator for the barrage.

Another notable discovery was a small masonry wall constructed in a shallow depression *ca.* 0.7m deep. Interestingly, it was not located immediately under the barrage wall but was slightly offset. This suggests that it was probably added as a retaining wall to protect against erosion than as a foundation for the barrage wall itself. This feature was found only in the vicinity of the braided channel of the wadi; no parallel examples were identified elsewhere at Barrage 2 or at Barrage 1. It is therefore possible that the small depression represents the remnants of an earlier braided channel that pre-dates the construction of Barrage 2. If this is the case, the retaining wall may also have functioned as a reinforcing wall to help bridge the natural depression. Either way, this possible trace of an earlier braided channel is highly significant in the sense that it provides valuable insights into the formation process of the Wādī Ghuwayr barrage system.

Surrounding Small Features

In addition to the two barrages described above, we located two small stone concentrations on the west bank of the little wadi that drains out of the playa (Fig. 4). Both features included a pillar base analogous to the finds from Barrage 1.



29. Barrage 2: stone weight incorporated into the barrage wall of Area 2 (looking north).

Stone Concentration 1

This small feature, *ca.* 1m by *ca.* 1.5m in area, was located *ca.* 350m north-west of Barrage 2 (Fig. 4). It contained a few dozen small limestone cobbles, most of which lay on the present ground surface (Fig. 30). The date and function of this nondescript feature is unknown, but a relatively later date seems likely in view of its stratigraphic position. The stone concentration included a large pillar base comparable to that from Area 2 of Barrage 1 (Fig. 34: 3). The contextual correlation between the feature and the pillar base remains obscure, but there is little doubt that the artifact itself belongs to the same chronological horizon as the parallel example from Barrage 1. The occurrence of this diagnostic artifact near the material source is suggestive of on-site production.

Stone Concentration 2

This stone concentration was located *ca.* 200m north-west of stone concentration 1 (Fig. 4). A few dozen limestone cobbles *ca.* 20-40cm long were scattered across an ill-defined area measuring *ca.* 5m by *ca.* 3m (Fig. 31). Again, no reliable chronological indicator was obtained. A halved pillar base was found on the modern ground surface *ca.* 10m north of the main stone concentration (Fig. 34: 4). Although a contextual association between the artifact and stone concentration cannot be demonstrated, the fact it was found in close proximity to this possible source material hints at on-site production, as suggested above.

Small Finds

Small finds from the open-air barrage site



30. Surrounding small features: stone concentration 1 (looking north-west).



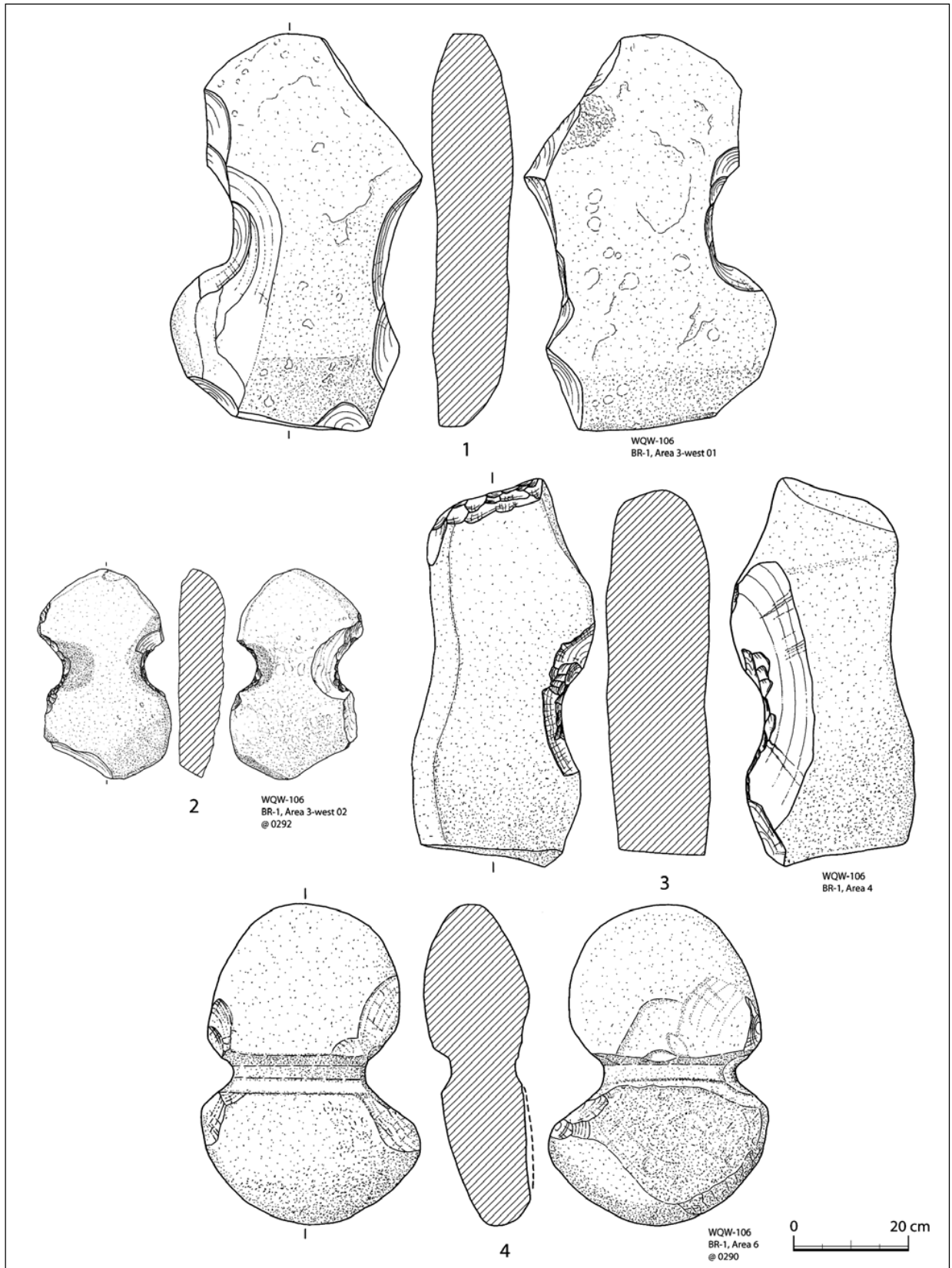
31. Surrounding small features: stone concentration 2 (looking south-east).

were understandably very scarce, being limited to ten limestone artifacts, four Thamudic inscriptions (including the two seemingly *in situ* finds described above), a small number of undiagnostic flint flakes and nodules, and several Arabic graffiti. Since the latter three groups can be regarded as later additions or stray finds, the following description focuses on the limestone artifacts only.

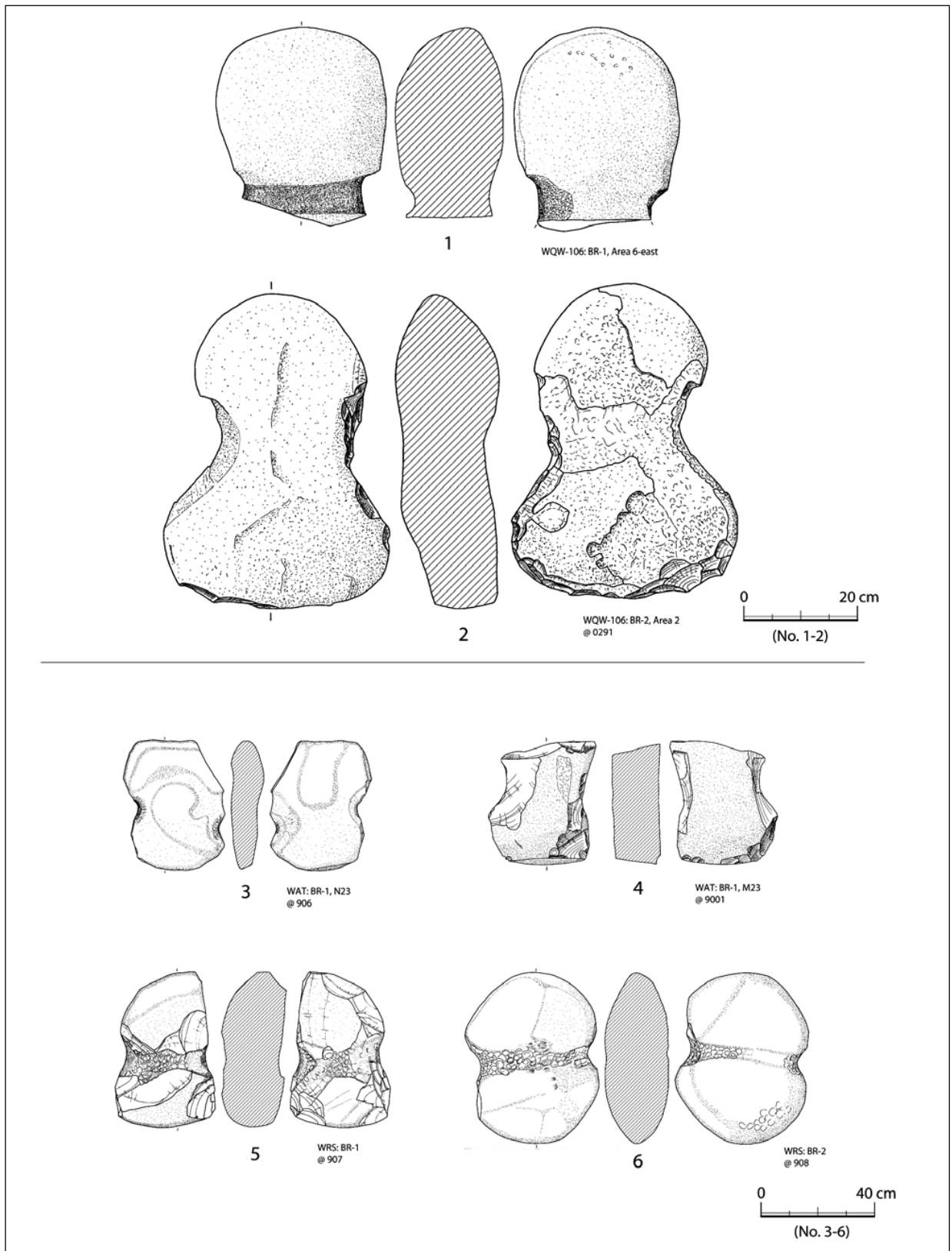
Stone Weights

The two barrages yielded a total of six bilaterally notched and / or bifacially grooved stone weights (Figs. 32 and 33). Five occurred at Barrage 1 (Figs. 32: 1-4, 33: 1) and the remaining example at Barrage 2 (Fig. 33: 2). In terms of context, three were found incorporated into the wall itself and can therefore be regarded as roughly contemporary with the barrages (Figs. 32: 3-4, 33: 2). The other three were recovered as stray finds, but there is little doubt that they originally were components of a nearby wall segment (Figs. 32: 1-2, 33: 1).

All six of the stone weights were made of relatively flat limestone cobbles or boulders. As already noted, suitable raw material can be still be found in the wadi bed a few hundred meters downstream of the playa. There is a strong possibility that the stone weights were produced at the material source and brought to the barrages. Large examples more than 50cm long (*ca.* 50-60kg in weight) were predominant, but a smaller example *ca.* 35cm long (*ca.* 10kg in weight) was also recovered. In general, they were violin-shaped, being characterized by a pair of lateral notches. A few examples had a pair of grooves connecting the two notches.



32. Stone weights: Wadi Ghuwayr 106.



33. Stone weights: Wādī Ghuwayr 106 (nos 1-2), Wādī Abū Ṭalayḥa (nos 3-4) and Wādī ar-Ruwayshid ash-Sharqī (nos 5-6).

Similar artifacts have been found at PPNB barrages and outposts in the western Jafr basin (**Fig. 33: 3-6**). It appears that the finds from Wādī Ghuwayr 106 are of a similar nature and age. Three of the six stone weights from Wādī Ghuwayr 106 occurred in and around the reinforcement wall of Barrage 1. It is possible that they were produced as good luck talismans, being incorporated into the key wall as ritual objects intended to secure the safety and longevity of the barrage. An alternative interpretation is that they were in some way associated with construction of the barrage and then subsequently re-used as construction material. The former interpretation seems more likely in view of their limited distribution, but further investigation is needed to confirm how these unique artifacts were used. Either way, the incorporation of a large stone weight into the key wall is a common feature of Jafr PPNB barrages (Fujii 2007b: Fig. 16, 2007c: Fig. 9, n.d.a) and may well have been the norm. In this sense, we can argue that the Wādī Ghuwayr barrage system belongs to the same cultural horizon.

Pillar Bases

A total of four pillar bases were recovered, two as more or less *in situ* finds in Area 2 of Barrage 1 (**Fig. 34: 1-2**) and the other two in association with the stone concentrations (**Fig. 34: 3-4**). All were made of an undressed or part-dressed limestone slab, *ca.* 40-50cm long and *ca.* 30-50kg in weight, and each had a small concavity, *ca.* 2-3cm deep and *ca.* 7-8cm in diameter, roughly in the centre. Other modifications are rare, being limited to rough trimming around the edges.

It is most unlikely that these pillar bases were used for their original purpose in the context of the barrages, because the *in situ* find from Area 2 of Barrage 1 was placed on edge (**Fig. 13**). It is also unlikely that they were carried in from a nearby settlement and incorporated into the barrage walls as re-used construction materials, primarily because no settlements are known in the immediate vicinity. The PPNB outpost of Wādī Ghuwayr 17 (Fujii *et al.* this volume) is one possible exception, but it seems improbable that the builders of the barrage would have taken the trouble to carry such heavy objects over *ca.* 6km. In view of the proximity to suitable source

material and the absence of a neighboring settlement, it is more likely that – as with the stone weights – the four pillar bases were produced near the wadi, with only two of them being brought up the barrage. Our tentative interpretation is that they were produced as ritual objects from the beginning, but further investigation is needed to validate this assumption.

Similar objects have been found at the PPNB outposts of Wādī Ghuwayr 17 (Fujii *et al.* this volume) and Wādī Abū Ṭulayḥa (e.g. Fujii 2007a: Fig. 30). Our recent re-examination of Barrage 1 of Wādī Abū Ṭulayḥa also recovered two comparable examples (**Fig. 34: 5-6**). There is little doubt that the finds from the Wādī Ghuwayr barrage system are of similar date.

Summary and Discussion

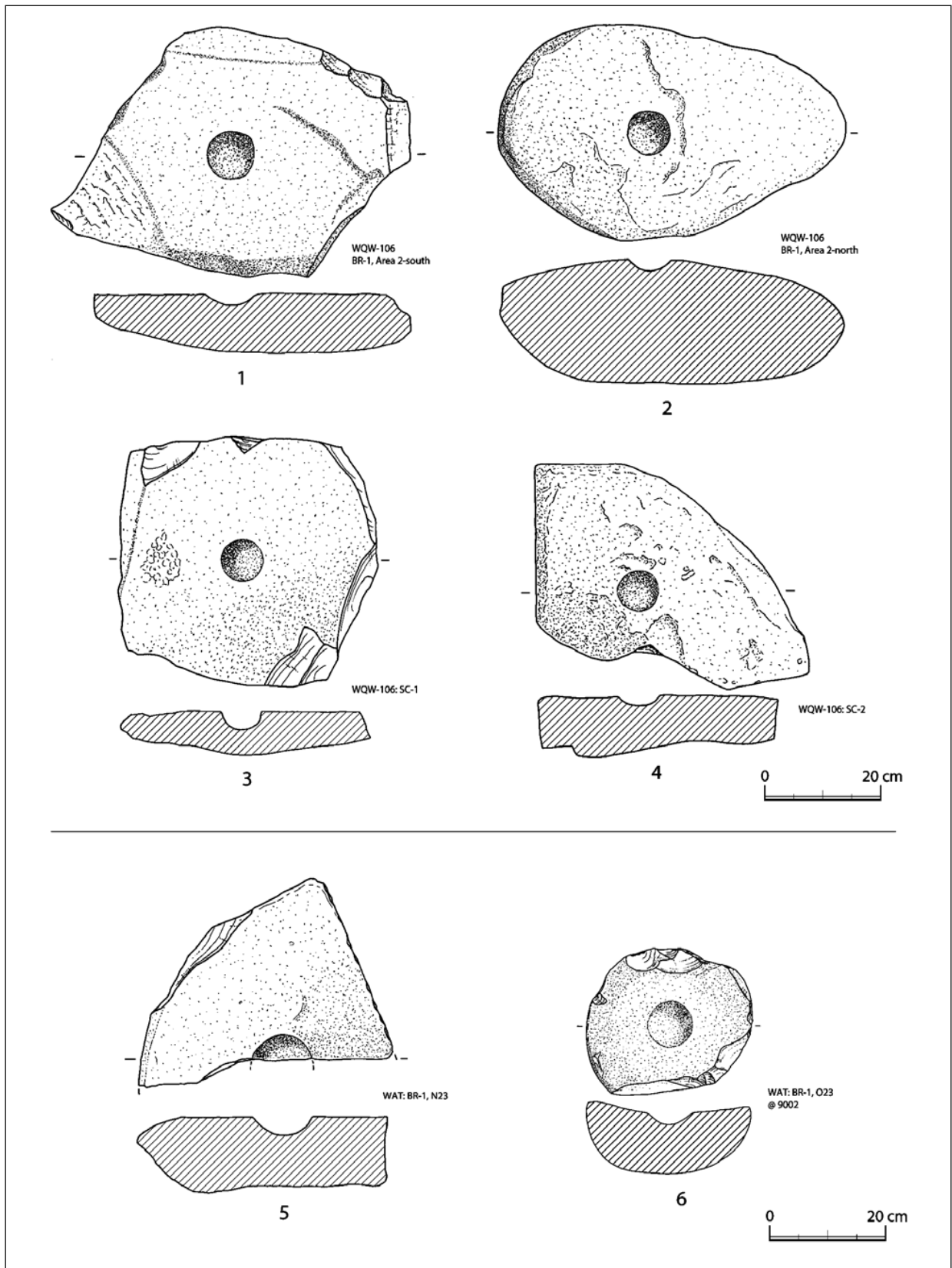
The excavation demonstrated that the unique, open-air site of Wādī Ghuwayr 106 represents a third example of a Jafr PPNB barrage system, after Wādī Abū Ṭulayḥa and Wādī ar-Ruwayshid ash-Sharqī (Fujii 2007b, 2007c, 2010a). The following discussion briefly considers the results of the investigation.

Date

Ample evidence supports the attribution of the two barrages to the PPNB period, including the *in situ* occurrence of several diagnostic finds. We should note that similar objects were found at the nearby PPNB outpost of Wādī Ghuwayr 17 as well as at Wādī Abū Ṭulayḥa (Fujii *et al.* this volume). The occurrence of analogous limestone products at a well-dated settlement in the same area deserves special emphasis. Another line of evidence is the existence of the semi-circular, protruding reinforcement wall attached to the central part of Barrage 1. Similar features have been identified at Barrages 1 and 2 of Wādī Abū Ṭulayḥa (Fujii 2007b: Figs. 9, 22, 2007c: Figs. 7, 9) and Barrage 2 of Wādī ar-Ruwayshid ash-Sharqī (Fujii 2007b: Fig. 30, 2007c: Fig. 9, 12). Although no C14 data are available from the open-air barrage sites, there is little doubt that the Wādī Ghuwayr barrage system dates back to the PPNB.

Function

That the two elongated, stone wall alignments at Wādī Ghuwayr 106 were used as water



34: Pillar bases: Wādī Ghuwayr 106 (nos 1-4) and Wādī Abū Tulayḥa (nos 5-6).

catchment facilities seems certain: (1) because both occupy the lower half of the elongated playa, (2) because they were constructed across the dry lake bed and (3) because they were slightly incurved in the direction of the upper course of the drainage. Only water catchment facilities could be expected to have such characteristics.

Regarding their function, we should note that not only were they constructed on permeable terrain - being designed to form an extensive, shallow flooded area - they were also low in height and far from watertight. It is therefore rather unlikely that they served as dams in the strict sense of the word. Instead, it seems more reasonable to assume that they were used to regulate seasonal runoff, thereby promoting the impregnation or saturation of the ground. In this sense, they can be defined as basin-irrigation barrages, as suggested for the similar examples known from the western Jafr basin. One should also consider the possibility that such a system could supply additional water and / or anthropogenic grazing for pastoral stock, thereby facilitating agro-pastoral adaptations on the desert landscape.

Conditions for the Location of Jafr PPNB Barrage Systems

The investigation at Wādī Ghuwayr 106 has shed new light on the locational requirements of Jafr PPNB barrage systems. First, any two adjacent features of the playa system are connected by a braided or flat channel, thus forming a semi-open drainage system. Second, only the lowest playa is associated with the barrage system; the upper playas are left untouched. Third, the two barrages are located at the bottom half of the lowest playa. It follows, therefore, that the Wādī Ghuwayr barrage system occupies the lower half of the lowest feature of the semi-open playa system.

The reason for this is easy to understand, given that such a location makes it possible to create an extensive flooded area. Otherwise, one couldn't take full advantage of the topographical potential of the playa. The reason for the first and second requirements (see above) is difficult to specify, but we can argue that in comparison with upper or closed features, the lowest feature of a semi-open playa system is easier to feed and drain. As a result, it would be less subject to salt damage, an unavoidable problem besetting dry-

land irrigated agriculture. The two other barrage systems known so far in the Jafr basin are likewise located on the lowest playa(s) of a semi-open drainage system; no barrages have been identified on the upper playas of the same system, nor on the numerous closed playas of the basin. This indicates that the Jafr PPNB barrage system gave as much priority to convenience of drainage as to inputs of surface run-off water.

When these new observations are combined with our previous knowledge, the conditions for location of the Jafr PPNB barrage systems can be summarized as follows. First, available surface run-off water had to be easy to control and, therefore, moderate in volume. It is precisely for this reason that a side stream incorporating a playa system was preferred over major tributaries or the main stream of a wadi. Second, a sufficient quantity of large and heavy building material capable of withstanding strong water pressure had to be close at hand. Numerous areas fulfilling the first condition fail to meet the second, although it should be added that Jafr barrage systems occasionally substituted an earth bank for a stone-built wall, as evidenced at Barrage 2 of Wādī ar-Ruwayshid ash-Sharqī (Fujii 2010a). Third, the side wadi needed to have cultivable soil in its bed; a gentle stream associated with a playa system would have been preferable in this sense. Fourth, the terrain to be flooded not only had to be flat and extensive, but also permeable as well as water-retentive. This is because basin-irrigation depends on infiltration of captured water into the subsoil and its subsequent retention. It is probably for this reason that a silty playa rather than a rocky or sandy depression was preferred for the Jafr barrage systems. The final requirement was that inflowing surface water should dampen the ground and, at the same time, wash through it to a certain extent to prevent salinization by capillary action. For this reason, semi-open playa systems were preferred over closed ones and, within them, the lowest features were preferable to upper ones.

It is unlikely that the barrage constructors struggled to reach this conclusion. This is because present vegetation is also concentrated on the lowest component(s) of semi-open playa systems, being scarce on upper or closed features even after heavy rain. The truth may be that they simply followed the distribution of

contemporary vegetation, and followed the example of existing vernal pools and their seasonal biotic systems. This behavior should be considered an excellent example of early sustainable agricultural practices based on a full understanding of environmental constraints. It is particularly noteworthy that the Jafr PPNB barrage systems, including that of Wādī Ghuwayr 106, were constructed to reconcile the two contradictory requirements of dryland agriculture, namely, irrigation and soil desalinization. This interpretation reasonably explains why there was no requirement for the Jafr PPNB barrages to be completely watertight.

Correlation Between the Two Barrages

Another point of interest concerns the functional correlation between the two adjacent barrages. A key aspect of this question is the structural difference between the two. As noted above, Barrage 1 was equipped with a protruding reinforcement wall and short additional wall, in addition to the slightly incurved main wall. In contrast, Barrage 2 was less strengthened in structural terms, being equipped with just the L-shaped main wall. This is probably because Barrage 2 was located downstream of Barrage 1 and was therefore subject to less water pressure. Viewed in this light, Barrage 2 might be a later addition to Barrage 1, although the occurrence of the diagnostic stone weight indicates that the episode still falls within the time range of the PPNB period.

However, the construction order suggested above seems counter-intuitive, because Barrage 2 has a considerable advantage over Barrage 1 in terms of the availability of building material as well as the scale of the supposed flooding area. A key to this enigma is the trace of a braided channel revealed at Area 2 of Barrage 2, which implies that the original playa was smaller in dimensions than the present one. It is therefore possible that Barrage 1 was constructed at the lower edge of the original playa. Following the same line of argument, Barrage 2 might then have been added at a later date, taking advantage of the downstream expansion of the playa resulting from the construction of Barrage 1.

Were the two barrages used in combination? This question is essential to understanding the functioning of the Jafr PPNB barrage system.

We can only argue that they formed a barrage 'system' if they were used together to increase the productivity of basin-irrigated agriculture. It is however conceivable that upper barrage was affected by salinization, which in turn prompted the construction of a new barrage on less saline ground formed at the lower edge of the now expanded playa. If this were the case, it would follow that downstream renewal is the most important aspect of the Jafr PPNB barrage system. The latter interpretation seems more likely in view of the site formation history of the contemporary outpost of Wādī Abū Ṭulayḥa (Fujii 2009 : 206), which suggests cycles of repeated use and abandonment over a long period of time. This tentative interpretation cautions against overestimation of the intensity and long-term stability of the Jafr Pastoral Neolithic, and deserves further examination.

Correlation with Wādī Ghuwayr 17

The next question concerns the community who operated the barrage system; who exploited and managed this basin-irrigated agricultural field in the middle of a flint strewn desert? The PPNB agro-pastoral outpost of Wādī Ghuwayr 17 (Fujii *et al.* this volume) is the nearest known encampment, although it is *ca.* 6km from the barrage system. Its artifacts are however both chronologically and functionally consistent with the period and function of the barrage system. For example, it yielded a large number of grinding implements and serrated blades, probably sickle elements, which together reflect crop harvesting and processing. Since no suitable arable land was available close to the outpost, there is a good likelihood that the barrage system functioned to support its agro-pastoral activities.

A similar relationship has been proposed for the barrage system of Wādī ar-Ruwayshid ash-Sharqī and the contemporary outpost of Wādī Abū Ṭulayḥa (Fujii 2007b, 2007c, 2010b, n.d.a). Thus, the combination of an agro-pastoral outpost with an enclave agricultural field that incorporated water catchment and pasturage may have been a common feature of the Jafr Pastoral PPNB. Quite why these two essential site components appear to have been so widely separated is difficult to explain, but it is conceivable that this was the result of differences in their respective functional requirements. As noted above,

the Jafr PPNB barrage systems were based on quite tightly defined topographic and hydrological parameters. The location of a pastoral outpost would have been governed by subsistence considerations that emphasized other factors, such as proximity to hunting areas and flint sources, and the availability of drinking water, fuel and shelter. Considered in this light, it is unsurprising that the barrage system and its associated settlement were slightly displaced from each other. Needless to say, in both the western Jafr region of Wādī Abū Ṭulayḥa and the remote uplands of the eastern Wādī Ghuwayr people found a way to interweave both components into a viable system. We may argue that such flexibility was essential to survival in these arid peripheries.

Correlation with Wādī Abū Ṭulayḥa

To begin with, we should recall that the outpost of Wādī Ghuwayr 17 consisted only of a single structural complex, and that this had much in common with Complex I at Wādī Abū Ṭulayḥa (Fujii *et al.* this volume). It follows that Wādī Ghuwayr 17 is a single-phase outpost established at more or less the same time as Complex I of Wādī Abū Ṭulayḥa, that is, at the very end of the MPPNB or very beginning of the LPPNB (Fujii 2009: 203). This in turn means that the nearby barrage system would have been used for that limited time only. The reason why the two Wādī Ghuwayr sites were established at this time is of particular interest. Pertinent in this regard is the formation process noted at the outpost of Wādī Abū Ṭulayḥa. We have previously argued that the period represented by Complex I witnessed resettlement. This proposes reoccupation of the arid region after a short hiatus, an episode that was associated with the introduction of new technology in the form of the barrage system (Fujii 2008: 475-477). This interpretation – the barrage-supported pastoral reoccupation hypothesis – fits well with the brief appearance of the Wādī Ghuwayr site complex.

The Wādī Ghuwayr site complex sheds new light on the processes of pastoral nomadization suggested at Wādī Abū Ṭulayḥa (Fujii n.d.b). We have already argued that the Jafr PPNB barrage system may have been renewed downstream as a result of surface soil salinization. However, continual downstream renewal would eventually have become incompatible with the

desired location at the lower edge of the lowest feature of a semi-open playa system, unless the playa itself continued to expand downstream as a result of barrage construction. This limitation may explain why the barrage-supported agropastoral outpost of Wādī Ghuwayr 17 was so short-lived, and why the occupational history of the other known barrage-supported outpost (i.e. Wādī Abū Ṭulayḥa) appears to have been occasionally interrupted and renewed (Fujii 2009: 206). Assuming that remote outposts must have been periodically abandoned, we may argue that Jafr PPNB barrage-backed transhumance had the potential for pastoral nomadization from its earliest stages, regardless of the climatic deterioration suggested at Wādī Abū Ṭulayḥa (Fujii 2009: 206-207, n.d.b).

Concluding Remarks

The investigation at Wādī Ghuwayr 106 has not only identified a third example of a PPNB barrage system, but has also shed new light on the unique locational requirements of such systems. We are now able to explain the reason why the Jafr PPNB basin-irrigation barrage focused on the lowest feature of a semi-open playa system, why it was renewed downstream to rejuvenate the barrage system, and why it was likely to be separated from its operating body or populace to maintain an agricultural field. There is no doubt that the barrage system was a key supporting component of the Jafr PPNB pastoral occupation. Personal communications from colleagues and local inhabitants alike suggest that similar systems occur up to and beyond the Saudi Arabian border. If this is the case, it follows that the Jafr PPNB barrage phenomenon will broaden our understanding of the process of Neolithization in the northern half of the Arabian Peninsula as well as that of pastoral nomadization in southern Jordan. This makes sense when one considers that exploitation of surface run-off water was an essential pre-requisite for full-fledged movement into the arid peripheries (Mithen 2010: 5256-5266). The next field season, scheduled for the summer of 2011, will continue efforts towards gaining a more comprehensive understanding of the Jafr Pastoral Neolithic.

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